RHIC Science & Technology Review 2005

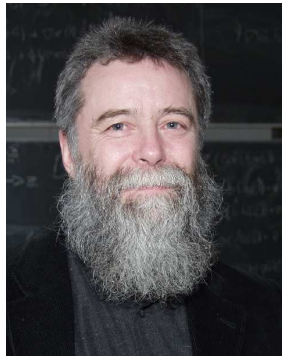
The Lattice Gauge Theory Group

- The new LGT group and the BNL environment
- Research activities
- Conclusions

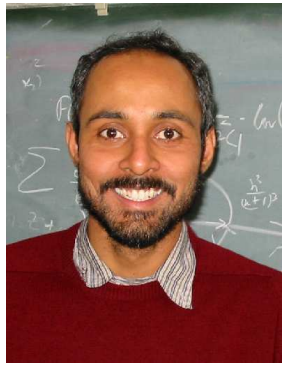
Excerpt from Field Work Proposal (2005)

- A new theory group will be formed...to exploit new ultra scale computing capabilities at BNL for lattice gauge calculations ... at finite temperature. This capability will build on existing expertise in theoretical nuclear physics and lattice gauge computation at BNL, and will complement the world-leading experimental effort in this area at the RHIC facility.
- Finite temperature QCD simulations on the lattice will be crucial in the interpretation of new phenomena observed at RHIC....These include the nature of the QCD phase transition, the properties of the Quark-Gluon Plasma, including the strange quark content and the equation of state.

The lattice group at BNL



Frithjof Karsch,
group leader
(since 02/05)



Saumen Datta,
Assistant Scientist
(since 07/05)

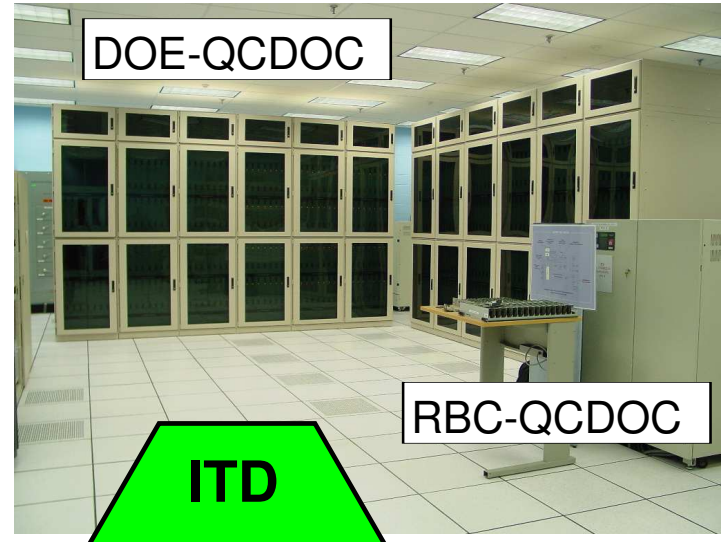
Christian Schmidt,
Res. Associate
(since 04/05 in NT;
joins LGT in 09/05)

Peter Petreczky,
Res. Associate, NT group
(since 10/02; joins LGT as
Assistant Sci. 09/05)

Takashi Umeda,
Res. Associate
(since 06/05)

N.N.,
Res. Associate
(FY 2006)

Lattice Gauge Theory @ BNL

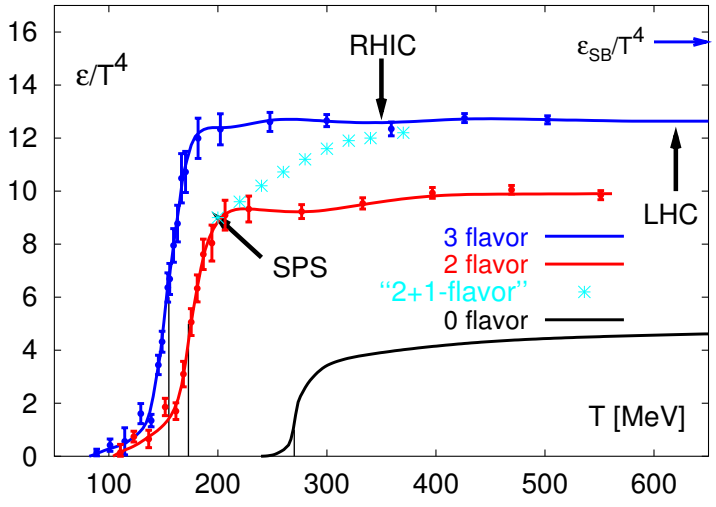


- LGT group focusing on QCD thermodynamics is the second main pillar for the theoretical support of the experimental heavy ion program at BNL

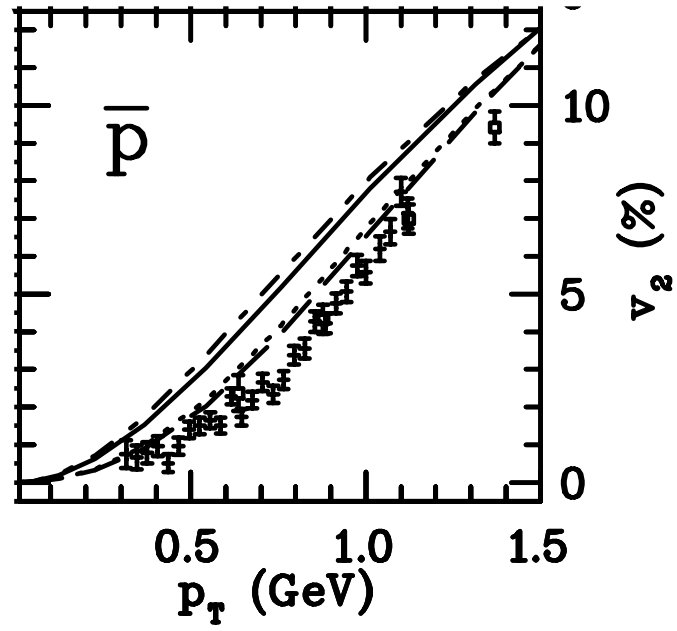
Research Activities

- QCD thermodynamics
  - equation of state and critical temperature
  - thermodynamics at non-zero baryon number density
  - Charge fluctuations and baryon number correlations
  - structure of the QCD phase diagram
- In-medium properties of hadrons
  - light quark sector: χSB and thermal dilepton rates
  - heavy quark sector: deconfinement and quarkonium
  - Hadrons at $T \neq 0$ and QCD with dynamical light quarks

Equation of State



state-of-the-art EoS (LGT)

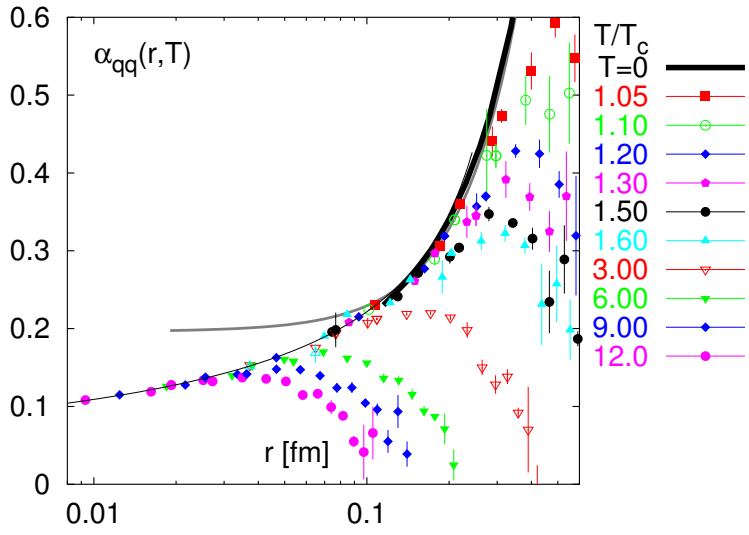


hydrodynamics, elliptic flow

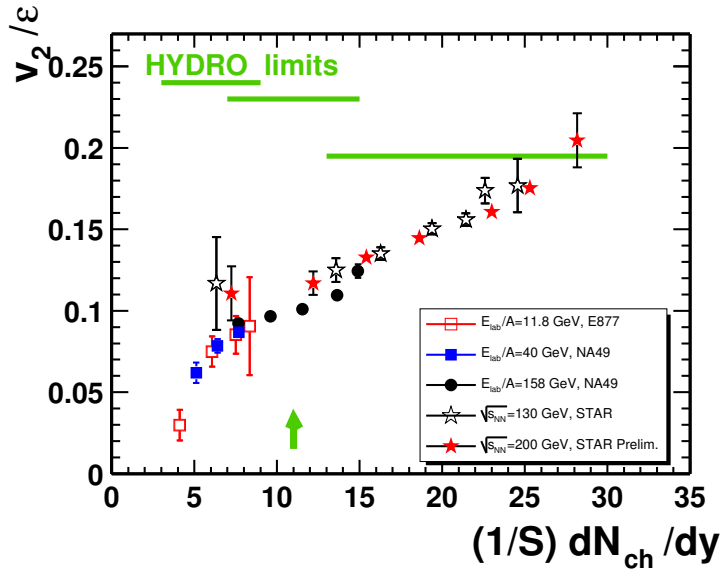
- $T_c = (173 \pm 8 \pm sys)$ MeV
  $\epsilon_c = (0.3 - 1.3)$GeV/fm^3
  - ϵ/T^4 for $m_\pi \simeq 700$ MeV; quark masses still too large
- hydrodynamics is sensitive to the QCD EoS
  - steep EoS $\Rightarrow$ small velocity of sound $\Rightarrow$ less elliptic flow

bound states or quasi-particles? – sQCD or HTL resummation?
small quark masses require huge computational effort $\Rightarrow$ QCDOC

Strongly coupled QCD



running coupling at finite-T (LGT)

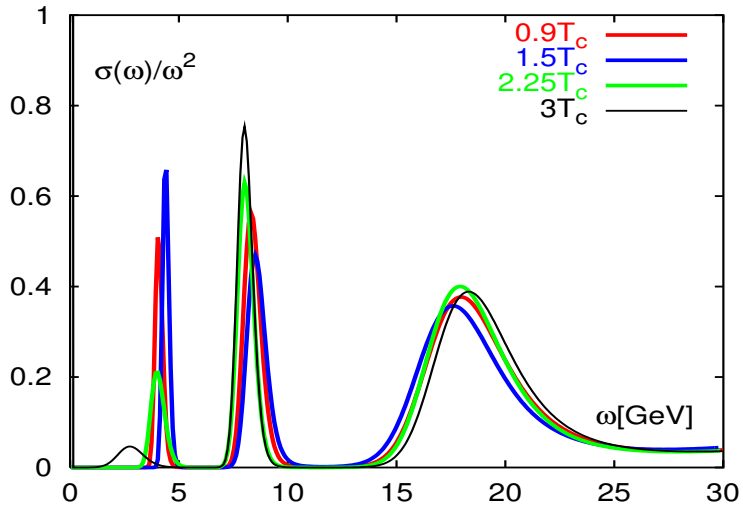


elliptic flow (RHIC)

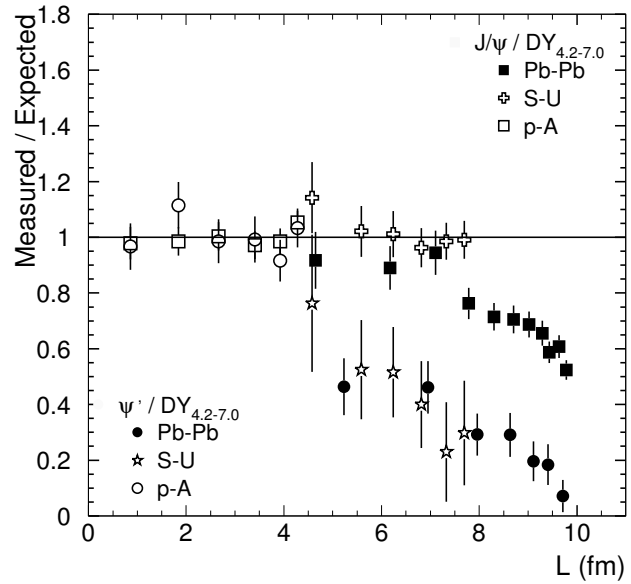
- T-dependence of $\bar{q}q$ interaction at short and medium distance reflects asymptotic freedom as well as remnants of confinement
- large elliptic flow suggest the creation of an almost perfect fluid in a heavy ion collision at RHIC

Is there evidence for colored bound states or density correlations that could give support to the sQCD scenario suggesting a fluid phase generated at RHIC ?

Deconfinement and Quarkonium suppression



in-medium spectral functions



charmonium yield (SPS)

- T-dependence of spectral functions reflects dissolution of heavy quark bound states
- lattice discretization errors limit current predictive power

- SPS: quarkonium yield is suppressed at high energy density
- Conversion of absorption length (L) into a temperature requires knowledge of the EoS

Does the charmonium suppression at SPS turn into charmonium enhancement at RHIC ? Does it show up in the bottomonium spectrum?

Dedicated Computer Resources for LGT

- The new generation of computers dedicated to LGT computations increases the resources available to the LGT community by more than an order of magnitude
- Resources – dedicated to studies of QCD thermodynamics – increase by more than a factor 50
- At present, most of these resources are located at BNL
  - The LGT group at BNL will make use of this unique constellation.
  - It has set up a QCD thermodynamics project that will significantly improve our knowledge on the QCD equation of state, the QCD phase diagram and the structure of the high temperature phase in a temperature regime relevant for RHIC physics

Thermodynamics on QCDOC

DOE
QCDOC

MILC
Spectrum
54,0%

LHPC (MIT)
Hadron Structure I
9,4%

LHPC (JLAB)
Hadron Structure II
11,3%

RBC-UKQCD
Decay matrix elements,
spectrum, topology, ...
10,8%

RBC
QCDOC

QCD vacuum with
domain wall fermions

$RBC - BI$
$Thermodynamics$

4.8 TFlops QCDOC
+ ($\sim$ 2) TFlops APE
devoted to QCD Thermodynamics
during the next year

Conclusions

- The new LGT group at BNL had a perfect start:
  It is fully integrated in the BNL environment
- The computing resources at BNL (QCDOC) and the well established international collaborations of the group allow to perform research on QCD thermodynamics at the forefront of the field during the rest of the decade
- Now is the time to start thinking about ”life after QCDOC”